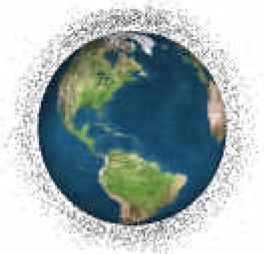
The Orbital Debris Quarterly News

July 2000 Volume 5, Issue 3



A publication of

The Orbital Debris Program Office
NASA Johnson Space Center

NEWS

LMT Data Reduction Continues

K. Jarvis

NASA has been collecting and analyzing data recorded through a 3-meter zenith staring liquid mirror telescope (LMT) located in New Mexico since April 1996. The data acquired permits analysis of altitude, inclination, and size of debris for LEO. The only limiting factors of the detection range for the LMT are size and albedo. Approximately 401 hours were collected from October 1997 through January 1999 using a microchannel plate with about a 0.42 degree field of view. In this data set, the LMT detection shows a falloff at a diameter of about 11 cm based upon
See Figure 1. With
plate the smallest
capable of
centimeter diameter
albedo of 0.1
orbit) at an altitude
this equates to an
visual magnitude.

Out of 401 hours,
for objects seen
targets (CTs), 441
nosees. Of the
on multiple nights
of unique CTs were
10% were
duplicity average of
potentially 53
objects, indicating
have been
most of the objects
seen and assuming
progression,
that in LEO, a
estimate of total
(altitude < 2000

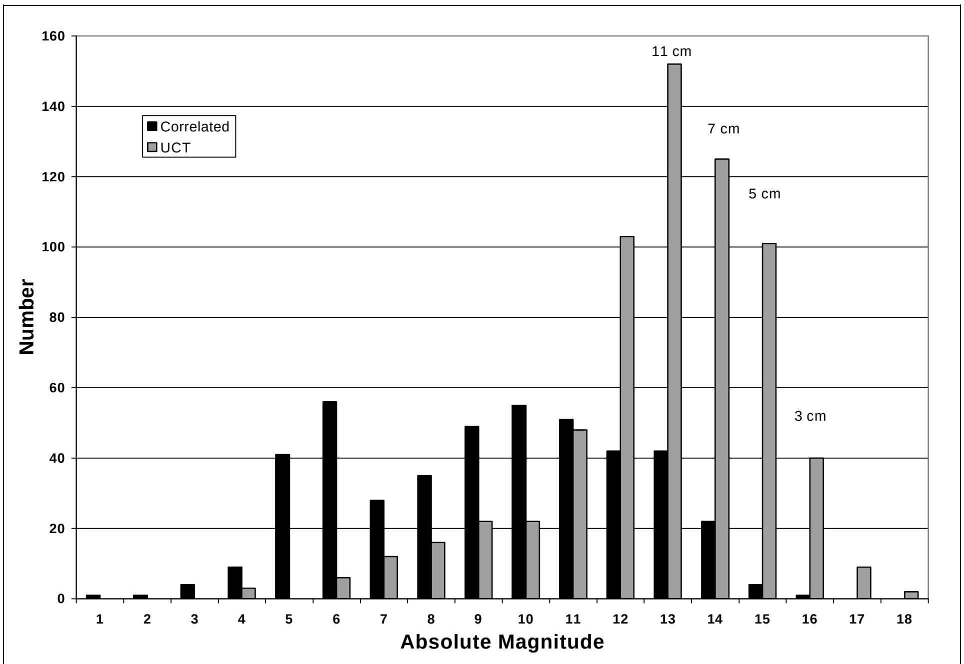


Figure 1. Absolute Magnitude Distribution for data from 10/97 to 01/99.

existing radar data.
this microchannel
object the LMT was
detecting was a two-
object with an
(assuming a circular
of 1000 kilometers;
object with a 17.5

the counts returned
were 389 correlated
UCTs and 127
CTs, 14% were seen
meaning the number
332. Of the nosees,
duplicates. Using a
12%+/- 2%,
UCTs were repeat
388 unique UCTs
observed. Assuming
down to 5 cm were
a polynomial
analysis suggests
conservative
untracked debris

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Inside...

LMT Data Reduction Continues, Continued

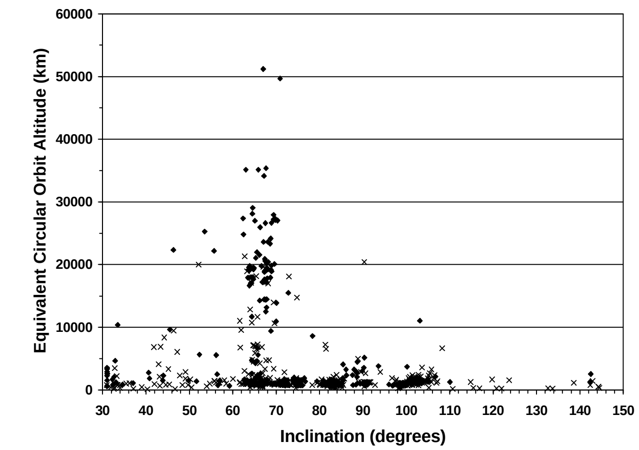

Figure 2. Data from 10/97 to 01/99. All detections to 60000 km are displayed. A 2 degree correction has been applied to the inclinations. The 2 degree bias in this data has since been reduced 0.5 degrees or less by applying a more accurate Earth model. Solid diamonds represent correlated targets while Xs

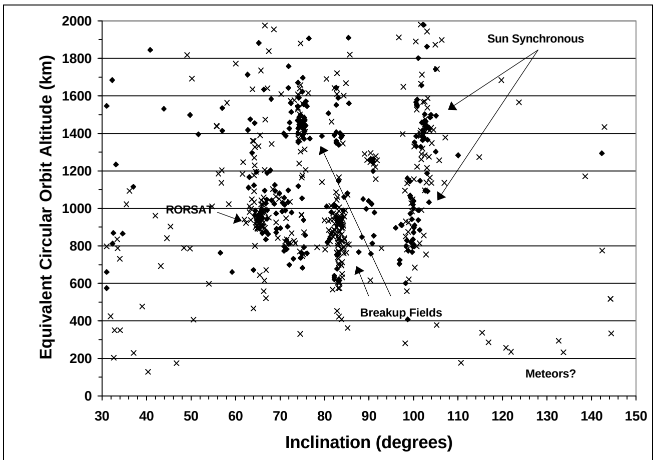

Figure 3. Data from 10/97 to 01/99. All detections to 2000 km are displayed. A 2 degree correction has been applied to the inclinations. A few of the general debris areas are identified. Solid diamonds represent correlated targets while Xs represent

(Continued from page 1)

The microchannel plate suffered a failure in January 1999 and a new microchannel plate with a smaller field of view (~.24 degrees) but higher sensitivity came on line in March of 1999. To date, about 240 hours have been collected. Of those, about 130 hours have been reduced and are undergoing analysis. Because the shadow height limits viewing time at lower elevations, the actual observation hours at the lower elevations are not 130 hours. Data reduction of the other 110 hours will proceed shortly.

Preliminary results of the 130 hours of data indicate that the LMT has found 341 uncorrelated targets and 101 correlated targets for a total of 442 objects seen. Of the correlated targets, 6 have been duplicates; this is reasonable when compared with the previous data as the new field of view has a smaller viewing area. Assuming ~6% duplicity, 20 of the UCTs could potentially be duplicates, leaving 321 unique objects. A falloff at a diameter of about 11 cm occurs with this data as well. See Figure 4. This may indicate a limiting factor of detection or may imply characteristics of the orbital debris environment. As the data only represent half the number seen in the 97-99 data set and analysis is still

(Continued on page 3)

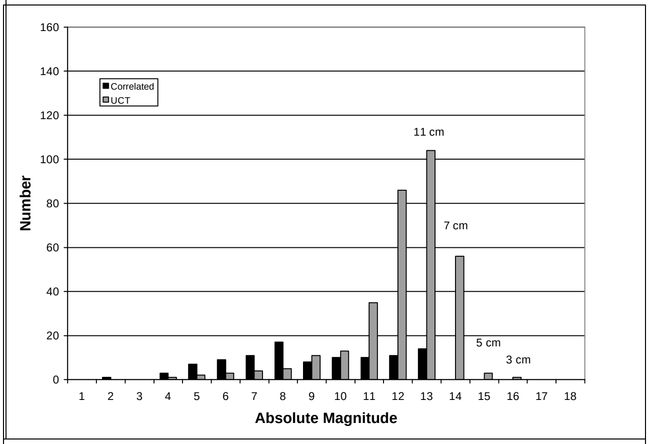

Figure 4. Absolute Magnitude Distribution for data from 03/99 to 11/99.

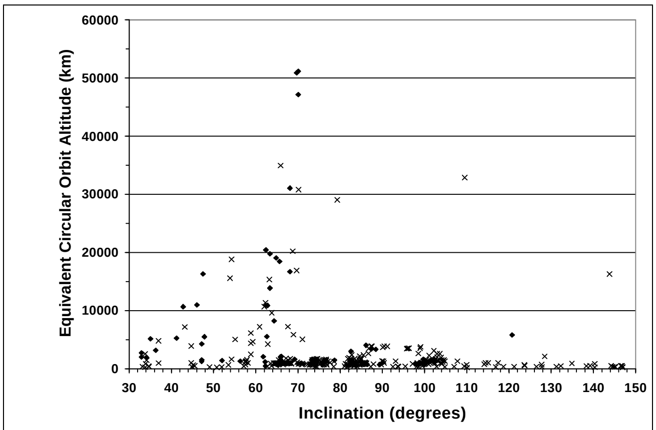

Figure 5. Data from 03/99 to 11/99. All detections to 60000 km are displayed. Inclination error is 0.5 degrees or less. Solid diamonds represent correlated targets while X's represent UCTs.

LMT Data Reduction Continues, Continued

(Continued from page 2)

For figures 2, 3, 5 and 6, objects below 500 km … e confirmed. For figures 3 and 6, a few general gro… f UCTs, as would be expected. In Figure 6, sun … e groupings, and few UCTs and no correlated

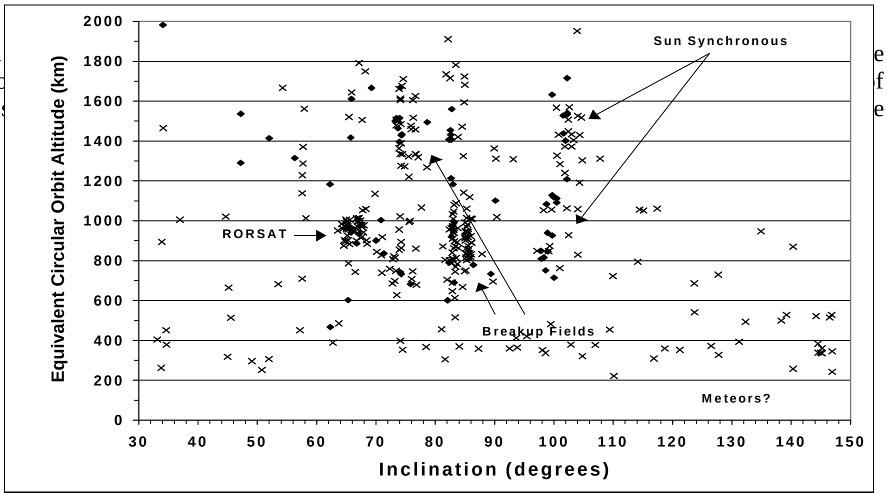

Figure 6. Data from 03/99 to 11/99. All detections to 2000 km are displayed. Inclination error is 0.5 degrees or less. Solid diamonds represent correlated targets while Xs represent UCTs.

Compton Gamma Ray Observatory Successfully Deorbited

In accordance with a 24 March announcement by NASA Headquarters, the Compton Gamma Ray Observatory (CGRO) was successfully deorbited over the eastern Pacific Ocean on 4 June. The 5-day maneuvering sequence to bring CGRO down from its 510 km circular orbit was flawlessly executed by the spacecraft control team at the Goddard Space Flight Center. In addition, a joint NASA JSC – Department of Defense operation to collect valuable reentry breakup data was accomplished.

The decision to initiate the long-planned deorbiting of the nearly 14 metric ton (dry mass) spacecraft was prompted by the failure in December 1999 of one of three gyroscopes (*Orbital Debris Quarterly News*, January 2000, pp. 6-7). To avoid taking a calculated risk of 1 in 1,000 that someone in the world might be injured by falling debris, a precisely controlled reentry in an uninhabited, broad ocean area was selected. The early June reentry date was advantageous both for the spacecraft power system (due to orbital lighting conditions) and for observing the reentry with airborne optical and infra-red sensors.

A series of very small engineering maneuvers, lasting less than a total of 4 seconds, was performed on 27 May, verifying that all thrusters were operational and ready for the four large maneuvers which would be needed to deorbit CGRO. The first major burn occurred early on 31 May, lasted 23 minutes, and resulted in lowering the perigee of CGRO to 364 km. A second, 26-minute burn was conducted about 25 hours later, lowering perigee to 250 km.

Burns 3 and 4 were scheduled about an hour and half apart early on 4 June. The nearly 22-minute Burn 3 reduced CGRO's perigee to about 150 km, the minimum altitude considered safe to ensure survival of the spacecraft for at least 24 hours. This strategy allowed time to implement contingency procedures if Burn 3 was non-nominal. The fourth and final burn commenced at 0522 UTC on 4 June and lasted for 30 minutes, dropping perigee to only 50 km, i.e., placing CGRO on a reentry trajectory.

Attitude control of the spacecraft was maintained until 0609 UTC, followed by loss of communications at 0610. The breakup of CGRO probably began about one minute later at an altitude of 78 km near the location of 14.7 N, 127.7 W. The estimated 6 metric tons of surviving debris should have impacted the ocean starting about 600 km downrange of the reentry point and extending for more than 600 km beyond that point.

At the time of reentry a U.S. Air Force aircraft was deployed over the Pacific Ocean to train its optical and infra-red sensors along the reentrying spacecraft's trajectory. The precise performance of the reentry maneuvers placed CGRO at exactly the predicted location and time,

Reexamining GEO Breakups

Recent searches for orbital debris at GEO altitudes by NASA and ESA, in support of an action item of the Inter-Agency Space Debris Coordination Committee (IADC), have revealed a significant population of uncataloged objects. To assess these data more completely, NASA's Orbital Debris Program Office has reviewed known and hypothesized satellite breakups near the GEO regime.

To date, only two breakups near GEO have been confirmed. The first subject, the Ekran 2 spacecraft, suffered a catastrophic battery malfunction on 23 June 1978. Three new debris were observed, but none have been cataloged. On 21 February 1992, 22 debris from a Titan Transtage (1968-081E) were observed, apparently only one-half hour after a fragmentation event.

(Continued on page 4)

Reexamining GEO Breakups, Continued

(Continued from page 3)

The latter breakup was accompanied by a distinct, albeit slight, orbital perturbation. At least four other Transtages (two below GEO and two above GEO) have also exhibited discrete orbital perturbations after many years in orbit. A hypothetical debris cloud was simulated for one of these four vehicles (1966-053J), propagated to January 2000, and compared with the observed uncataloged objects. No correlation was found, suggesting that no large debris (>20 cm) were created at the time of the orbital perturbation. Similar analyses are planned for the other three Transtages, and more sophisticated debris searches are being considered.

As many as 20 other GEO satellites (18 Soviet/Russian, 1 Japanese, and 1 Italian) have been suggested as possible breakup candidates based solely on orbital perturbations. However, these perturbations, if real, are the result of changes in velocity of much less than 1 m/s. Such a change is much smaller than normally associated with a breakup event, either by explosion or collision, and could be induced by other mechanisms.

The NASA study has identified a LEO precedent of orbital perturbations not unlike those seen with the Titan Transtages. Over 100 of the more than 400 Comos 3M second stages placed in LEO have exhibited significant orbital perturbations, some as long as 10 years after launch. Most of the events represent a single impulse, but several vehicles clearly experienced multiple small impulses over many days or weeks. In only one case (1991-009J) were these orbital perturbations linked to debris production events. The cause of these orbital perturbations is believed to be the venting of residual propellants – the same propellants as used by the Titan Transtages.

The preliminary results of this study were presented at the 18th meeting of the IADC in June. A more comprehensive summary will be

The Pitfalls of a Poor Random Number Generator in Monte Carlo Orbital Debris Models

D. T. Hall

Flaws in random number generation algorithms can potentially introduce significant inaccuracies in Monte Carlo projections of orbital debris populations. In the NASA EVOLVE 4.0 orbital debris model, using a flawed random number generator (of the type commonly provided on many commercial computer systems) can artificially skew explosion rates by a few percent, and can bias collision rates by 40% or more.

The most basic component of any Monte Carlo calculation is the random number generator that, ideally, produces a completely random sequence of numbers distributed uniformly over the interval 0 to 1. In a Monte Carlo simulation, each random number, R, is used to help make a decision. For instance, the EVOLVE orbital debris model uses random numbers to help decide when an unstable rocket-body might explode, or when an on-orbit collision might occur. Recent analysis has shown that it is critical for the random number generator used in the EVOLVE calculation to be robust in the limit of small values of R as well as in the limit of small values of the quantity $1 – R$.

Explosions are generated in the EVOLVE simulation by comparing a random number, R, to the probability that each object will explode sometime during its orbital lifetime, P_{ex}. If $R < P_{ex}$, then the object explodes in the simulation and an appropriate debris cloud is added to the orbiting population. Most orbiting objects are classified as non-explosive and have $P_{ex} = 0$. Explosion probabilities for discarded rocket bodies span the range 10^{-2} to 10^{-1}, and these objects dominate the exploding population in EVOLVE simulations. However, almost half of all explosive objects in EVOLVE have $P_{ex} \approx 7 \times 10^{-4}$. This class includes spacecraft with moderately unstable components such as batteries or depleted propellant tanks. For the correct number of explosions to occur in this special class, the random number algorithm must generate a uniform sequence in the range $R \le 7 \times 10^{-4}$. Our analysis indicates that some common random number generation algorithms fail in this regard (i.e., produce too many or too few values with $R \le 7 \times 10^{-4}$) and can potentially skew explosion rates for this class of object by about 2.5%.

In addition to explosions, EVOLVE must calculate the expected number of on-orbit collisions per time-step per volume-element per particle size-bin, defined here as Q_c. Because debris collisions are rare events, most values of Q_c calculated by EVOLVE are very small numbers, much less than one. In this case, Q_c is more intuitively regarded as the probability of a collision occurring, and typical values span the range $10^{-9} \le Q_c \le 10^{-3}$. Collisions are generated in EVOLVE simulations by comparing Q_c to the quantity, $1-R$, where R is produced by a random number generator. If $1-R < Q_c$, then a collision occurs in the simulation and the two colliding objects break-up and generate a debris cloud. Because probabilities for on-orbit collisions can be so much smaller than for explosions, a flawed random number algorithm can bias collision rates much more than explosion rates. In addition, because the collision probability, Q_c, is the expected number of collisions per time-step per volume element per particle size-bin, collision-rate inaccuracies introduced by a flawed random number generator will depend on the time-step, the size of volume elements and the width of each size-bin used in the calculation. For instance, when using the nominal 50 km altitude spacing to define volume elements, a commonly-employed flawed random number generator can bias EVOLVE collision rates by up to 40%. For 10 km altitude spacing, such inaccuracies can grow up to 250%, demonstrating that that a faulty random number generator may introduce a very large, non-linear bias in orbital debris collision rates.

To avoid these pitfalls, it is particularly important for Monte Carlo orbital debris models to employ robust random number generators. NASA's EVOLVE 4.0 model employs the random number function RAN2 given in the "Numerical Recipes" compendium (W. H. Press et al., 1989, Cambridge University Press). Testing indicates that this algorithm generates uniformly distributed random number sequences down to the limit where either R or $1 – R$ approach values as small as 10^{-10}, ensuring accurate calculation of on-orbit explosion and collision rates in orbital debris projection calculations. ❖

Orbital Debris Informational CD

E. Cizek

An informational CD titled "Orbital Debris at JSC" has recently been produced for distribution within NASA, other US Government agencies, industry, and to the international community. The CD contains data from the Orbital Debris web site along with additional related information and graphical animations. Major topics on the CD include Orbital Debris Research at JSC, Modeling, NASA Evaluation Model, Protection, Measurement, Mitigation, FAQ and The Orbital Debris Quarterly Newsletter. Special features include automatic startup when the CD is inserted into the CD-ROM drive, downloadable software, photographs of impact features and orbital debris animations from the 1998 videotape *Orbital Debris Animation*.

Update of the Satellite Breakup Risk Assessment Model

M. Matney

NASA developed the SBRAM model to assess the short-term risk to spacecraft (especially manned spacecraft) when there is a breakup of an on-orbit satellite such as a rocket body. SBRAM was created to provide decision-makers with the tools necessary to make informed decisions about crew safety and other safety issues.

The original version of SBRAM used the EVOLVE pre-1998 breakup model. In the last two years, however, the EVOLVE breakup model has undergone extensive improvements to try to match the observed behavior of debris objects. SBRAM has now been updated with the new EVOLVE breakup model to better reflect the hazard from on-orbit breakups. In addition, a new GUI is available to run the SBRAM program to make it easier to run.

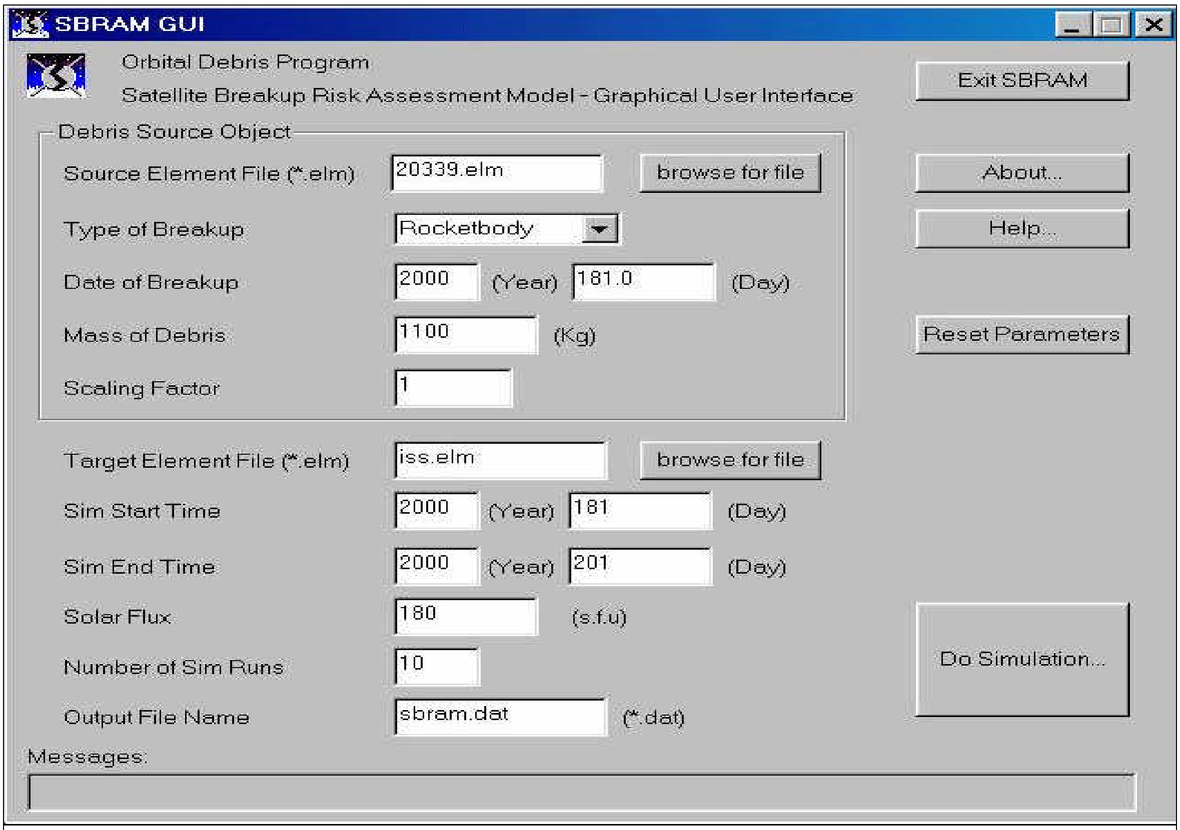

Figure 1 shows the GUI window used by SBRAM. The new breakup model is streamlined in the types of inputs needed to simulate the debris cloud, only requiring information on the type of breakup (spacecraft or rocket body), the mass of the body, and the scale factor – an empirical measure of the size of the cloud.

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Project Reviews

Update of the Satellite Breakup Risk Assessment Model (SBRAM),

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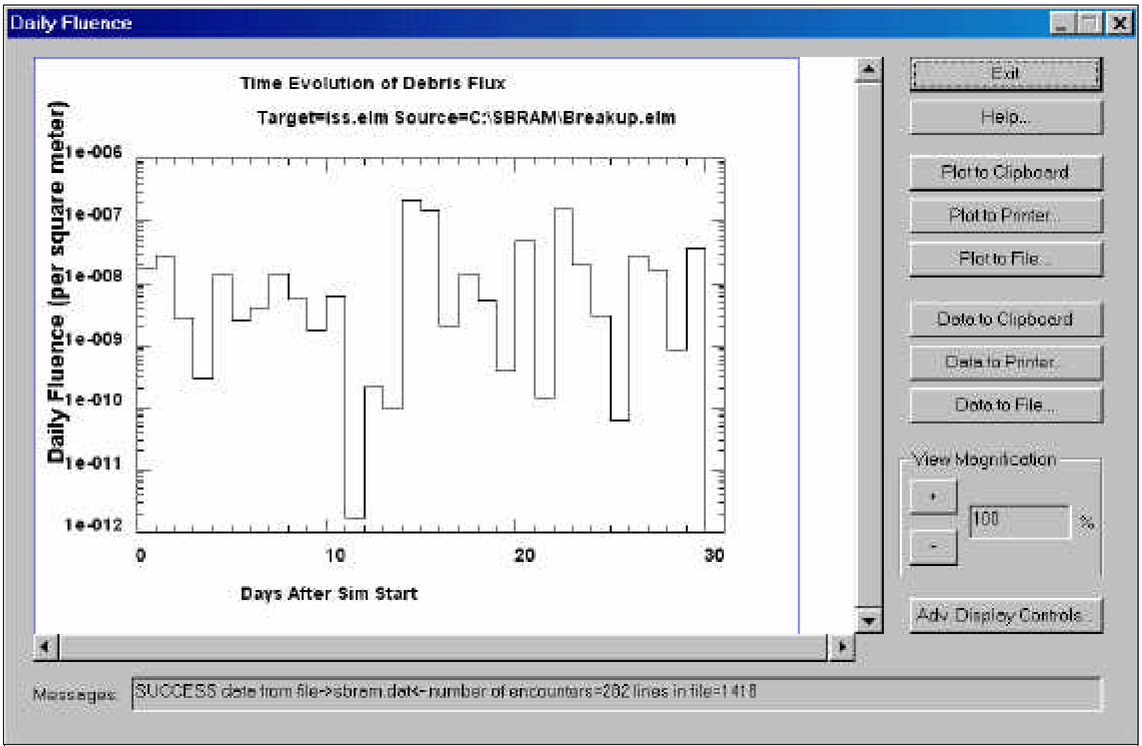

Figure 2 shows an output graph where the time-dependent flux on the target spacecraft is displayed.

Abstracts from Papers

NASA's New Breakup Model of EVOLVE 4.0

N. Johnson, P. Krisko, J.-C. Liou, P. Anz-Meador

Analyses of the fragmentation (due to explosions and collisions) of spacecraft and rocket bodies in low Earth orbit (LEO) have been performed this year at NASA/JSC. The overall goals of this study have been to achieve a better understanding of the results of fragmentations on the orbital debris environment and then to implement this understanding into the breakup model of EVOLVE 4.0. The previous breakup model implemented in EVOLVE 3.0 and other long-term orbital debris environment models was known to be inadequate in two major areas. First, it treated all fragmentational debris as spheres of a density which varied as a function of fragment diameter, where diameter was directly related to mass. Second, it underestimated the generation of fragments smaller than 10-cm in the majority of explosions. Without reliable data from both ground tests and on-orbit breakups, these inadequacies were unavoidable. Recent years, however, have brought additional data and related analyses: results of three ground tests, better on-orbit size and mass estimation techniques, more regular orbital tracking and reporting, additional radar resources dedicated to the observation of small objects, and simply a longer time period with which to observe the debris and their decay. Together these studies and data are applied to the reanalysis of the breakup model. In this paper we compare the new breakup model to the old breakup model in detail, including the size distributions for explosions and collisions, the area-to-mass and impact velocity assignments and distributions, and the delta-velocity distributions. These comparisons demonstrate a significantly better understanding of the fragmentation process as compared to previous versions of EVOLVE. ❖

Abstracts from Papers

Space Debris - Issues and Solutions
Space Storms and Space Weather Hazards Workshop, NATO Advanced Study

N. Johnson

Space debris, in particular, artificial debris or man-made refuse, poses a threat to human space flight and robotic missions in Earth orbit. To date, most attention to debris risks has been given to human space flight operations which require high levels of reliability and safety and involve vehicles which are typically much larger than robotic spacecraft. However, the artificial debris flux already exceeds that of the natural meteoroid environment for many important orbital regimes.

The degree of risk from artificial debris is dependent upon the size and construction of the satellite, the orbital characteristics, and the length of time that the satellite will remain in orbit. In addition, the artificial debris environment may be quite dynamic due to solar cycle effects, satellite fragmentations, the use of solid-propellant upper stages, spacecraft operations or malfunctions, and satellite surface degradations. Consequently, the consideration of potential space debris effects is now warranted in the early design phase for most space missions. Such assessments not only evaluate the effect of the space environment on the satellite mission, but also the effect of the satellite mission on the environment, including implications for future space missions.

Within NASA and the U.S. Government, guidelines and standard practices for debris mitigation have been developed. Mitigation measures can range from spacecraft and upper stage design and operational changes to mission orbit selection and disposal options. International recognition of these issues is also improving, as evidenced by the growth in membership of the Inter-Agency Space Debris Coordination Committee and the

Updating the NASA Debris Engineering Model: a Review of Source Data and Analytical Techniques
33rd Scientific Assembly of COSPAR

P. Anz-Meador, M. Matney, J.-C. Liou, N. Johnson

Orbital debris engineering models present a comprehensive view of the space environment to spacecraft designers and owner/operators. NASA is revising its orbital debris engineering model, ORDEM96, to incorporate approximately four years of new observations of the low Earth orbit (LEO) environment and new analytical methodologies. Since its last revision, significant measurements of the LEO environment have been made using radar and optical sensors (*e.g.* the Haystack and Haystack Auxiliary Radars and the Liquid Mirror Telescope) and returned surfaces (the Space Shuttle, the Hubble Space Telescope solar arrays, and the European Retrievable Carrier). This paper reviews the data sources and outlines analytical techniques used to reduce data to engineering quantities such as flux and directionality. Also, this paper describes one of the new analytical techniques - a method of building statistical distributions of orbit families. We use a Maximum Likelihood Estimator to take a given set of data and estimate the orbit populations that created that particular data set. This method precludes the ability to say whether a particular detected object is in a particular orbit, but it gives an overall picture of the debris families in orbit within the limits of the sampling error. ❖

EVOLVE 4.0 Orbital Debris Mitigation Studies

P. Krisko, N. Johnson, J. Opiela

In a continuing effort to limit future space debris generation, the NASA Policy Directive (NPD) 8710.3 was issued in May 1997. It requires all NASA-sponsored programs to conduct formal assessments in accordance with NASA Safety Standard (NSS) 1740.14 to quantify the potential to generate debris and to consider debris mitigation options. Recent improvements to the NASA long-term debris environment model, EVOLVE 4.0, allow for a reassessment of the effects of NSS mitigation measures on the projected debris environment. The NSS guidelines requiring the passivation of upper stages and spacecraft through depletion of on-board energy sources, and the post-mission disposal (PMD) of satellites may be studied with EVOLVE 4.0. In this paper, we present the results of a set of parametric EVOLVE 4.0 studies. We set our test matrix to include a draconian level of explosion suppression, *i.e.*, passivation, in future launches and PMD decay time periods of 50 years and 25 years. The PMD options are initiated at a time 10 years in the future. It is confirmed that explosion suppression alone effects only a minor change in the long-term environment. PMD implementation is required to significantly reduce it. But complications arise for the longest tested PMD lifetime (*i.e.*, 50 years). The enhanced dwell time at low altitudes (the dominant manned spacecraft region of Earth orbit) increases the likelihood that a collision will occur there compared to the lower PMD lifetime of 25 years. ❖

Visit the New NASA Johnson Space Center Orbital Debris Website

http://www.orbitaldebris.jsc.nasa.gov

Abstracts from Papers

Optical Observations of the Orbital Debris Environment at NASA
33rd Scientific Assembly of COSPAR

T. Hebert, *et al*

To monitor the orbital debris environment and facilitate orbital debris modeling and forecasting, the Orbital Debris Program Office of the NASA Johnson Space Center operates two principle telescopes: the liquid mirror telescope (LMT) and the charge coupled device debris telescope (CDT). Both telescopes are maintained at the NASA Cloudcroft Observatory, a 15 meter dome at 2761 meter elevation near Cloudcroft, NM. The LMT became operational in October 1996 and the CDT in November 1997. The CDT is currently being used in a statistical survey of catalogued and uncatalogued debris in geosynchronous earth orbit. Approximately 180 nights worth of data have been collected and results from a portion of this data are presented. A future direction for the CDT is to investigate various regions in GEO that would contain debris from hypothesized break-ups. Approximately 580 hours of digital video data from the LMT have been collected and processed by an automated hardware/software system. Results from some of this data re presented. In addition, this paper presents the results of a study of the detection sensitivity of the LMT system as well as a new measurement-based model for estimating object size from LMT

Meeting Report

18th Inter-Agency Space Debris Coordination Committee Meeting
13-16 June 2000 Colorado Springs, CO, USA

The Inter-Agency Space Debris Coordination Committee (IADC), hosted this year by the U.S. delegation, met at the United States Air Force Academy in Colorado Springs, USA during 13-16 June. The 11 members of the IADC represent the space agencies of China, France, Germany, India, Italy, Japan, Russia, the Ukraine, the United Kingdom, the United States, and the European Space Agency. Joining the IADC meeting for the first time, as an official observer, was the Canadian Space Agency.

In all, more than 110 specialists attended the meeting, which was organized into a steering group and four working groups: measurements, modeling, protection, and mitigation. Cooperative efforts (actions) within each working group continued and included a report of the geosynchronous regime (GEO) measurements campaign and a reentry campaign, debris environment model comparison studies, the application of a hypervelocity impact test facility calibration protocol to be recorded in the protection group's Protection Manual, and continuation of the discussion for the adoption of IADC mitigation standards.

The meeting was also marked by moves toward closer collaboration among the four working groups. In particular, the measurements group agreed to initiate a measurements database (accessible via the IADC website) for use by the modeling group. The modeling group provided projection studies to the mitigation group, which included predictions of the long-term environmental effects of LEO constellations and LEO storage orbits, and a comparison of postmission disposal options. ❖

Upcoming Meetings

16-23 July 2000: *33rd Scientific Assembly of COSPAR*, Warsaw, Poland. Four sessions on orbital debris are being jointly organized by Commission B and the Panel on Potentially Environmentally Detrimental Activities in Space to include such topics as techniques to measure orbital debris, methods of orbital debris modeling, hypervelocity impact phenomenology, and debris mitigation practices. For further information contact Prof. Walter Flury, wflury@esoc.esa.de

30 July-4 August 2000: *The International Symposium on Optical Science and Technology (SPIE's 45th annual meeting)*, San Diego, California, USA. The technical emphasis of the International Symposium on Optical Science and Technology confirms SPIE's commitment to a long-standing societal goal to create global forums that provide interaction for members of the optics and photonics communities, who gather to discuss the practical science, engineering, materials, and applications of optics, electro-optics, optoelectronics, and photonics technologies. The Annual Meeting also serves as an industry focal point, offering excellent interaction with the vendor community, who will be exhibiting their newest product developments. More information can be found at: http://www.spie.org/web/meetings/programs/am00/ am00_home.html.

2-6 October 2000: *The 51st International Astronautical Congress (IAF)*, Rio de Janeiro, Brazil. The theme for the congress is "Space: A Tool for the Environment and Development." The 51st International Astronautical Congress will offer a great opportunity for interactions and knowledge on innovative applications, new concepts and ideas, three debris sessions, and new scientific results and discussions. The Congress is open to participants of all nations. More information can be found at: http://www.iafastro.com/

INTERNATIONAL SPACE MISSIONS

March - June 2000

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2000-013A	EXPRESS 2A	RUSSIA	35783	35790	0.1	2	3
2000-014A	MTI	USA	573	609	97.4	1	0
2000-015A	DUMSAT 2	RUSSIA	267	17940	64.7	0	0
2000-016A	ASI ASTAR	USA	35764	35810	0.0	1	1
2000-016B	INSAT 3B	INDIA	35771	35802	0.0		
2000-017A	IMAGE	USA	1181	45799	89.7	2	0
2000-018A	SOYUZ TM 30	RUSSIA	359	378	51.7	1	0
2000-019A	SESAT	EUTELSAT	35779	35793	0.1	2	1
2000-020A	GALAXY 4R	USA	35786	35787	0.0	1	0
2000-021A	PROGRESS M1-2	RUSSIA	357	375	51.7	1	0
2000-022A	GOES 11	USA	35782	35789	0.2	1	0
2000-023A	COSMOS 2370	RUSSIA	237	289	64.8	1	0
2000-024A	USA 149	USA	ELEMENTS UNAVAILABLE			3	0
2000-025A	NAVSTAR 51	USA	20117	20251	54.9	2	0
2000-026A	SIMSAT-1	RUSSIA	545	556	86.4	1	0
2000-026B	SIMSAT-2	RUSSIA	543	554	86.4		
2000-027A	STS 101	USA	352	381	51.6	0	0
2000-028A	EUTELSAT W4	EUTELSAT	35730	35737	0.1	1	0
2000-029A	GORIZONT 33	RUSSIA	35783	35785	1.4	1	1
2000-030A	TSX-5	USA	404	1703	68.9	1	0
2000-031A	EXPRESS 3A	RUSSIA	35965	36082	0.1	2	1
2000-032A	FENGYUN	CHINA	35819	35931	1.1	1	0
2000-033A	NADEZHDA	RUSSIA	683	708	98.1	0	0
2000-033B	TZINGHUA 1	CHINA	684	708			
2000-033C	SNAP 1	UK	683	706			
2000-034A	TDRS H	USA	EN ROUTE TO OP. ORBIT			1	0
2000-035A	SIRIUS - 1	USA	EN ROUTE TO OP. ORBIT			2	1

Haystack (background) and HAX (foregraound) radar domes are NASA's main source of data for debris in the size range of 1-30 cm.

ORBITAL BOX SCORE

(as of 28 June 2000, as catalogued by US SPACE COMMAND)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	28	324	352
CIS	1333	2557	3890
ESA	24	228	252
INDIA	20	4	24
JAPAN	66	47	113
US	918	2907	3825
OTHER	286	25	311
TOTAL	2675	6092	8767

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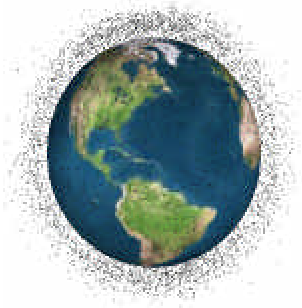

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